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PAPER MILL POLLUTION IN PUGET SOUND

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A difficult water pollution problem has existed in Puget Sound for many years. In an effort to find a solution, the State of Washington asked for enforcement action by the U. S. Department of Health, Education, and Welfare under provisions of Section 8 of the Federal Water Pollution Control Act. As a result of this request, a conference under the terms of the Act was held in January 1962 at Olympia, Washington, to determine the pollution status and remedial actions needed. It was concluded that measures taken to date by some of those contributing pollution to the waters of Puget Sound and the Strait of Juan de Fuca have not been sufficient to control the pollution, and that delays have been encountered in taking corrective actions. Seven pulp and paper mills were cited, in particular, as the principal sources of pollution that need correction. The conferees then recommended that a joint action program to bring about the abatement of the pollution be undertaken by the State and Federal Governments.

Puget Sound is a body of water tributary through the Strait of Juan de Fuca to the Pacific Ocean (Figure 1). It drains about 13,000 square miles of land. The water area of the basin is approximately 2,000 square miles. Many rivers, streams, canals and lakes drain from the east, south and west into the Sound and into the Strait of Juan de Fuca.

The pulp and paper industry has existed in Washington since before the turn of the century and has grown to a prominent national position as a producer of pulp wood, pulp, and paper. Most of the State's mills are located in the Puget Sound area, but seven, utilizing mainly the sulfite base process, contribute the largest percentage of the total pollution. They are located at Bellingham, Everett, Anacortes and Port Angeles, Washington. In terms of oxygen consumption, the more than 187 million gallons per day of wastes they discharge to Puget Sound are equal to the untreated sewage from more than eleven million persons.

The State's request for assistance in connection with this problem was the result of a long and inconclusive effort by the State to bring about the control of pollution from these sources. The conference records that, as early as 1940, efforts were undertaken by the State authorities to seek an equitable solution to the industry's waste disposal problems. Since May 1961 there has been a continous effort by

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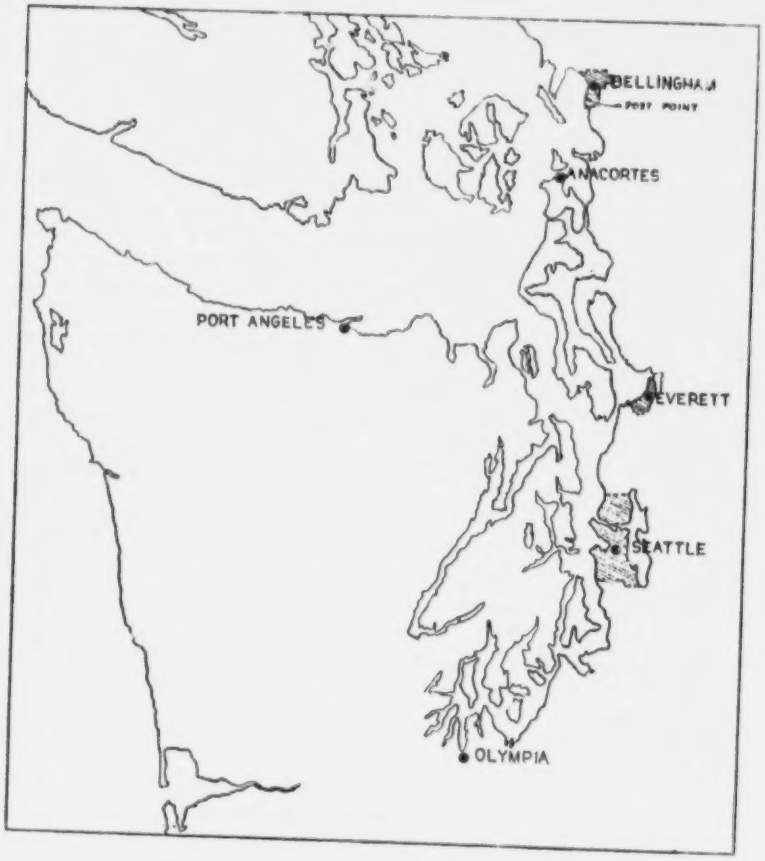

Figure 1.

the State to develop and specify waste disposal permits under which the mills' operations will not adversely affect water quality. In December 1962 permits were issued by the Washington Pollution Control Commission which, in effect, require immediate mill action on removal of suspended solids wastes, while postponing final consideration of sulfite waste liquor disposition until water quality conditions in the affected areas can be ascertained through field study.

STUDY PROGRAM

The study program on Puget Sound, growing out of the conferees' recommendation has been under way since April 1962. It includes field research and related studies at the four specified locations where pulp and paper mill wastes are discharged to the Sound waters. In developing the study plan, assistance was freely given by a Puget Sound Technical Coordinating Committee consisting of members from State and Federal agencies having responsibilities or interests related to water resources of the area. Appointments to the Committee were made so as to assure that knowledge, technical skills and other pertinent resources of the region can be brought to bear on the problem.

The over-all objective of this work is to determine the effects of the mill wastes on water quality, water uses, and the marine environment. The technical program consists of four interrelated elements: (a) inplant surveys to determine the origin, nature, and strength of wastes; (b) oceanographic studies to determine their distribution, dispersion, and persistence; (c) biological and chemical studies of the wastes and their effects on the marine environment; and (d) economic studies on the growth possibilities for the area, the timber and other resources.

Both State and Federal personnel are joined together in teams for unified attack on each phase of the program. At present, twenty-nine persons, including a number with highly specialized skills, have been incorporated with the effort on the Federal level. This number will likely grow to thirty-five or more next year. This total effort, spread over a two and one-half year period, is greater than has ever been brought to bear on the pollution problems of this industry any place in the world.

In-Plant Surveys

In-plant surveys are now getting under way, and one has been completed thus far. Although initial delays had been encountered in this phase of the program, a working agreement has now been developed for cooperative studies in some of the mills and on adjacent waters of the Sound.

The principal objective of the in-plant surveys is to more precisely identify each mill and characterize it as fully as possible as a source of pollution. Wastes from each process in the plant are sampled separately so that their strengths and character can be compared and the most offensive waste sources identified. Wastes are measured qualitatively and quantitatively and checked against production volume so that the data may have real meaning, can be

projected to other production levels, and can be compared with other mills. Waste character is examined in the light of the raw materials used which may have considerable impact on the nature of the wastes. The data gathered in this phase of work will permit developing a materials balance for the total process.

Finally, the individual wastes and the consolidated wastes that leave the plant will be characterized as fully as practicable. This effort will include physical and chemical analyses and bioassays with fish and other marine organisms. Information so obtained will permit anticipating the distribution, strength, and effects of the pollutants once they are discharged into the Sound. This information, then, lays the groundwork for the oceanographic studies.

Each mill will be surveyed for a 72-hour period on three separate occasions. Samples will be composited on a 24-hour basis and analyzed, and then these samples mixed for a 72-hour composite. The resulting data will be an adequate reflection of the character of the mill and its waste-producing capacity.

Oceanographic Studies

Once the waste load from each mill is known as a result of the in-plant surveys, the oceanographic studies will: (1) determine the dispersion, travel and persistence of sulfite waste liquor and other wastes from the mills in relation to currents and water movements during various seasons of the year, phases of the tide, and mill operations; (2) define sludge deposit areas, depths, and their nature; and (3) establish light penetration and light scattering characteristics in the vicinity of the mill outfalls.

For this phase of the project there has been assembled a staff of seven, equipped with modern oceanographic equipment. Initially, 38-foot and 65-foot vessels were chartered but present and future cruises will utilize the 45-foot Public Health Service vessel, *Harold W. Streeter*, built for this purpose at Bellingham, Washington.

As of January 1963, 17 extensive field trips in pursuit of these objectives have been made. Eight have been in the Everett area, two in the Bellingham area, two in the Anacortes area, and five in the Port Angeles area.

Studies in the Everett area to date show that sulfite waste liquor from a submarine diffuser outlet can be found at concentrations greater than 5 ppm[1] 10 nautical miles to the south, 17 miles to the north, and 13 miles to the northwest. A tendency for sulfite waste liquor to stratify was noted at different depths, depending on the density of the receiving waters. Concentric about the lines of high

[1]Pearl Benson Index.

sulfite waste liquor are isopleths of low dissolved oxygen and, to a lesser extent, low pH. At the depth of greatest oxygen demand and greatest sulfite waste liquor concentration, there is an excellent correlation of sulfite waste liquor concentration with dissolved oxygen concentration. This correlation applies to varying degrees at depths above and below this level.

Of the two cruises completed at Bellingham, one was concerned with current measurements, the other with water quality. Most of the future work in Bellingham will be concerned with current studies and water quality north and east of Post Point. This area has been selected for concentrated effort because the University of Washington has recently issued a volume of data listing observations of temperature, salinity, dissolved oxygen, sulfite waste liquor, and phosphate for Bellingham Bay west of Post Point. These data were collected over a 12-month period and their availability makes requirements for further observations in the larger area less urgent.

Current studies to date give a preliminary indication of a clockwise circulation in the Bay which essentially follows the bottom topography. Because the outfalls in the Bellingham waterway are recessed, there is little chance for initial rapid dispersion and dilution. Plans are now being developed for jointly using the current meters in possession of the University of Washington and the Public Health Service, so that by having 17 in the water at one time, the water movements and net transport of Bellingham Bay can be defined more precisely.

The results of several float studies and partial examination of dye released at Port Angeles indicate a complex current system. There appears to be a net movement toward the west end of the harbor at depths along the south shore with a net movement outward, or toward the east, at the surface most of the time. At the west end of the bay, there is a considerable amount of opaque, white wash water resulting from pulp washing. There are also large quantities of floating materials which have broken off from the bottom, but sulfite waste liquor concentrations in this part of the bay are generally fairly low. Near one mill at the east area of the bay, there are extremely high sulfite waste liquor concentrations. The distribution of sulfite waste liquor in the Bay changes radically with time, as a function of tide change and wind velocity.

Preliminary observations indicate that in the vicinity of the mills, fiber, bark and other solids of mill origin are deposited on the bottom and contribute to sludge bed formation. Such beds blanket the bottom but decrease in thickness with distance from the point of origin. Not only do such sludge beds inhibit the production of a normal fauna for

the area because of the physical suffocation of the habitat, but they also provide an anaerobic environment in which toxic hydrogen sulfide is produced. Several procedures involving scuba diving and core sampling will be used shortly to map the sludge areas, trace the vertical profile, and ascertain sludge composition.

Monthly oceanographic observations in the four study areas will be made so as to delineate the water movements as fully as possible over the full range of tides and seasons. To provide for more effective collection of meaningful oceanographic data within the two-year duration of the study, the most modern sampling, sensing, sample processing and recording equipment is being obtained. Among items now available and on order are a shipboard gas chromatograph, salinometer, recording fluorometer, recording dissolved oxygen meter, and several Richardson current meters. Under present arrangements, data processing is being done at the University of Washington Computer Center.

Biological and Chemical

Biological and chemical studies will further characterize the wastes and determine their effects on the marine environment. The principal wastes of concern are the used waters from barking, pulping, washing, bleaching, and paper making. In general, they are responsible for: (1) formation of sludge beds, (2) oxygen depletion, (3) toxic action, and (4) unsightly conditions. Determining how and to what extent they exert these actions is the function of the biological and chemical studies.

The problem is approached so as to detect and measure directly the influences of pollution on fish and shellfish resources and to measure them less directly by evaluating the changes wrought in the environment. Because anadromous fishes of several kinds use the waters near the mills as migration and feeding areas, data are gathered on fishkills that occur, on episodes of fish distress apparently attributable to pulp mill wastes, and on the extent to which fishes actually invade the areas and could therefore be vulnerable. Here as well as at other mill sites, live box bioassays using down-stream migrant salmon, herring and crustacean fish foods will be made to ascertain the occurrence, intensity and distribution of toxic conditions.

Concurrently, laboratory bioassays will be made with oyster and clam larvae using Pudget Sound samples collected at suspect stations near the mills. The samples will be flown to the laboratory by seaplane to shorten the time from collection to sample processing. The bioassay technique will be that used by the State of Washington Depart-

ment of Fisheries (Lindsay, *et al.*, 1960) which uses yield of embryos, their size and abnormal development as criteria of toxicity.

Claims have been made by some oyster growers that oysters that can survive and grow to maturity in waters receiving mill wastes do not fatten sufficiently to be marketable. To shed light on this phase of the problem development of oysters to harvestable age will be followed by placing them in floating rafts and anchoring the rafts at key points in the Sound. In these long-range tests, lasting two to three years, the survival, growth and marketability will be gauged against proximity to the mills, measurable water quality, and other pertinent factors.

A number of less direct biological approaches are being used, each to yield pieces of information which together portray the environmental responses to pollution that are occurring. In each of the four geographic areas, the biological tone of the environment will be detected and measured to determine if the biological populations and patterns have become altered as compared with unpolluted areas. Four times during the year populations of benthic and intertidal organisms will be collected, identified and productivity measured in terms of organism volume per unit of environmental space.

Plans are now under way to mark and release downstream migrant salmon in the Snohomish River near Everett so that the extent to which they inhabit the polluted Inner Harbor down-stream can be estimated from recoveries. Comparable work will be done as necessary at Bellingham, Anacortes and Port Angeles. Distribution of fry, juveniles, adults, and major food organisms will be found by sampling with various devices, including an inclined plane sampler, beam trawl, beach seines, and a purse seine.

Creel census data, historical records, and other sources of information are being scrutinized to add to the growing picture of the anadromous fisheries and their use of tributary streams.

Of great importance is knowing whether pulp and paper mill wastes impair the ability of the Sound waters to produce living matter. Obviously, without an adequate starting point of the food progression, the growth and production of fish and shellfish cannot proceed at a favorable rate. This question of productivity is approached in several ways. On four occasions during the year, glass slides are suspended in the water as a surface on which algae, protozoa and other organisms may become attached. These samples then are processed to determine the species present and numbers of each. Zoo-plankton populations are also sampled with Clarke-Bumpus and Wisconsin-type nets. Results are expressed in terms of numbers and volumes of organisms and species composition. Phytoplankton col-

lections are made utilizing Van Dorn samplers and results are expressed in terms of phytoplankton identification and in pigment (chlorophyll) concentration. In addition, basic productivity will be measured more-directly through use of the C14 technique.

Economic Studies

The specific economic studies now under way or proposed relate basically to the question of the impact of waste treatment, or its lack, on the economy of the area. The problem is approached along two lines. First, because waste treatment or other waste handling may be costly, additional treatment costs are examined. In order to properly measure and interpret their effect, the economic background of the pulp industry must be understood. Second, it is necessary to know the significance of the other uses of the Sound waters receiving the wastes and the relative importance to the region of these various components of the economy. Three studies, carried out by consultants under contract, are now nearing completion. The objective of the first is to describe and analyze the uses and possible benefits for several key in-place uses of water in Puget Sound that may be affected by inadequate water quality. The second will examine the present and historical economic base of both the Puget Sound area and the State and describe the major components of anticipated future change. The third will describe and analyze the Washington wood pulp industry with particular emphasis on the economic relationships of and within the sulfite mills.

CONCLUSION

It is the intent of this program to determine the effects of pulp and paper mill wastes on water quality, the marine environment and water uses. The methods, equipment and skills put to the task are the best attainable. The knowledge obtained will be used to determine what further remedial action is required of the seven mills concerned in the interest of restoring and preserving water quality in Pudget Sound.

LITERATURE CITED

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1960. Reports on sulfite waste liquor in a marine environment and its effect on oyster larvae. State of Washington Department of Fisheries Research Bull. No. 6.

DISCUSSION

MR. FISHER: Thank you very much, Mr. Bartsch. Now, are there any questions?

MR. GENE KANAGA [Midland, Michigan]: Since 1946, DDT has been used world-wide, and in the last 10 years, about a billion pounds of this material has been put upon this earth and we are now reaping the effects, as Dr. Springer has been pointing out, and the residue is very difficult to decompose. There are a number of other residual materials also on the market, and that is why we have been talking about all these residues. As a member of the chemical industry, however, I would like to point out there are some bright spots in the picture. I

haven't heard mentioned the gray tick killers, and other newer classes of insecticides which are readily decomposable and which leave non-toxic residues. In fact, some of the residues are actually components of the human body. It might be interesting to know that this year about 180 million pounds of DDT are being made. This is the level of this particular material being manufactured. It is estimated there will be about 60 million pounds of Malathion made this year, and perhaps close to 30 million pounds of Dymat Number Seven. So, you see, these new insecticides are indeed making inroads into our economy in regards to production, and I think the trends, while it seems like we are on the back roads here with regards to hydrocarbons, this black historic picture is now catching up with us, our future is now in this type of material.

MR. FISHER: Thank you very much.

MR. SPRINGER: Well, I certainly agree this is a commendable trend to develop safer pesticides. However, the problem isn't as simple as might be implied, because we are considering now the entire animal kingdom, practically, when we talk about wildlife, and there is plant life, too. You mentioned two compounds, Malathion, which is considerably safer to warm-blooded animals, certainly, than other chemicals. However, studies have shown it can be very toxic to fish. I didn't cite this example, but a study in Delaware, half a pound of Malathion, which is a standard application for mosquito control, killed one-third of the killi fish. This isn't a natural condition, but it shows the possibilities. Sevin again is safer to vertebrates, but I believe work in New York has shown that this is possibly just as toxic as DDT is to invertebrates, so the point is that we have to be very careful in using this material and try to use them where they will do the job and try not to hurt the other beneficial life that would be exposed to them. This isn't to say they both don't have a place, but they have to be tied in. Thank you.

F. H. LESSER [Delaware]: I would like to make a statement on impoundment as an alternative method for chemical control of insects, and other means to improve wildlife habitat. One fact that many people go on is the belief that we are trying to snap up all forms of marshes, and that is as far from the truth as can be. Most of them are not even suitable for impounding because of the nature of the marsh itself. They are not suitable for the construction of dikes, and also, mosquito control is a most important facet now for supporting these impoundment studies. They are using impoundments upon salt water, and these are mostly used on tidal marshes that are of a much higher nature and firmer bottom which provides a suitable habitat, and another point that many people bring out is that productivity of the marshes provide all the nutrients for tidal estuaries. Well, this has been borne out in many studies, but most of the studies were concentrated along the tidal kick-backs where all the diatoms and what-not that are produced in the inter-tidal zone are necessary for the development of sport fish and good fisheries. There have been very few studies made in the higher tidal marshes that are impounded for mosquito control, and I theorize that possibly these higher marshes not only constitute a large amount of nutrients which are washed into the bay, but also in conjunction, there is the water in the ponds constructed around the edge of these impoundments. They have additional exposed tidal and inter-tidal mud flats that produce an additional amount of nutrients that can be washed into the bay, so until further studies are carried out, possibly these impoundments are producing more nutrients that are washed into the bay than are utilized or retained inside. Thank you.

MR. FISHER: Yes?

MR. RONN [Conservation Foundation]: I was very interested in what Bob had to say about Puget Sound and the area in which it was involving wastes, and I would just like to mention we have some serious situations in the East. I don't know if anybody here knows of any similar studies being carried on in the Penobscot or other rivers. I think we have a serious situation here, too.

MR. FISHER: Thank you. Are there any other questions or comments? If not, I would like to thank the speakers very much for their earnest cooperation in meeting this time problem we have at these large meetings.